



US006346924B1

(12) **United States Patent**  
**Heinz et al.**

(10) **Patent No.: US 6,346,924 B1**  
(45) **Date of Patent: Feb. 12, 2002**

- (54) **ANTENNA CONTROL SYSTEM**
- (75) Inventors: **William Emil Heinz; Mathias Martin Ernest Ehlen**, both of Wellington (NZ)
- (73) Assignee: **Andrew Corporation**, Orland Park, IL (US)
- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
- (21) Appl. No.: **09/713,614**
- (22) Filed: **Nov. 15, 2000**

4,241,352 A	12/1980	Alspaugh et al. ....	343/700
4,427,984 A	1/1984	Anderson .....	343/764
4,532,518 A	7/1985	Gaglione et al. ....	343/372
4,564,824 A	1/1986	Boyd, Jr. ....	333/137
4,575,697 A	3/1986	Rao et al. ....	333/157
4,652,887 A	3/1987	Cresswell .....	343/766
4,714,930 A	12/1987	Winter et al. ....	343/786
4,717,918 A	1/1988	Finken .....	342/368
4,768,001 A	8/1988	Chan-Son-Lint et al. ...	333/159
4,788,515 A	11/1988	Wong et al. ....	333/160
4,791,428 A	12/1988	Anderson .....	343/758
4,804,899 A	2/1989	Wurdack et al. ....	318/600
4,814,774 A	3/1989	Herczfeld .....	342/372
4,821,596 A	4/1989	Eklund .....	74/479
5,162,803 A	11/1992	Chen .....	342/372
5,181,042 A	1/1993	Kaise et al. ....	343/700
5,184,140 A	2/1993	Hariu et al. ....	342/372

**Related U.S. Application Data**

- (63) Continuation of application No. 08/817,445, filed on Apr. 30, 1997, now Pat. No. 6,198,458.
- (30) **Foreign Application Priority Data**
  - Nov. 4, 1994 (NZ) ..... 264864
  - Aug. 15, 1995 (NZ) ..... 272778
- (51) **Int. Cl.<sup>7</sup>** ..... **H01Q 21/00**
- (52) **U.S. Cl.** ..... **343/853; 343/757; 343/763**
- (58) **Field of Search** ..... **343/853, 757, 343/763, 766, 765, 778**

(List continued on next page.)

**FOREIGN PATENT DOCUMENTS**

AU	933874	5/1993
AU	9341625	6/1993

(List continued on next page.)

**OTHER PUBLICATIONS**

Specifications: Mobile Telephone Panel Array (MTPA) Antenna, Field Adjustable Downtilt Models; Deltec New Zealand Limited.

(List continued on next page.)

(56) **References Cited**  
**U.S. PATENT DOCUMENTS**

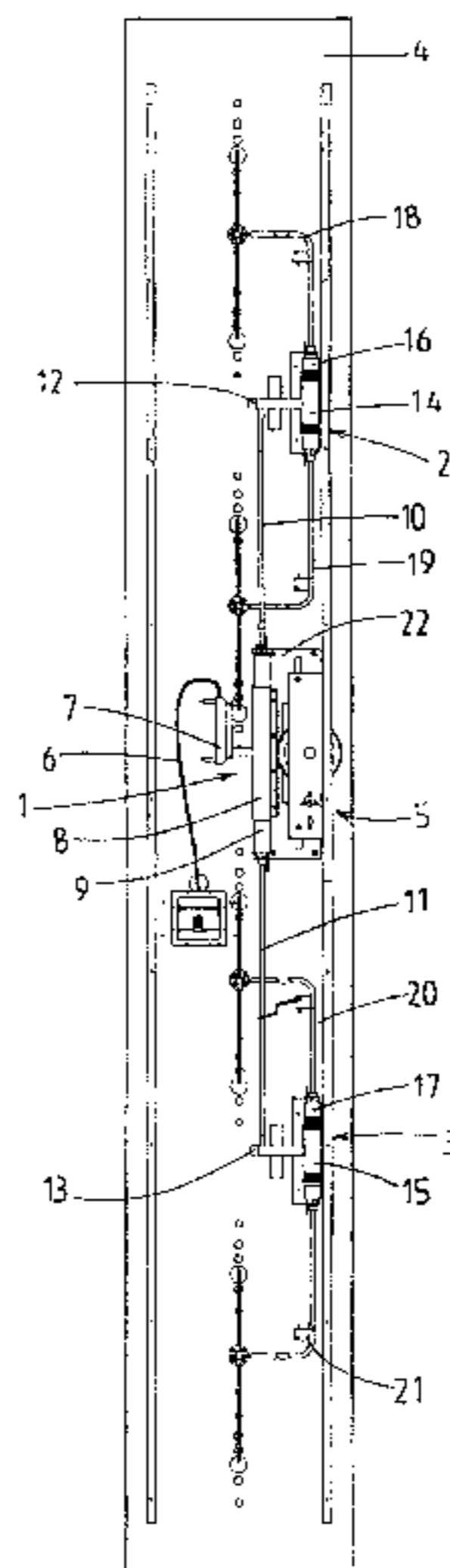
2,041,600 A	5/1936	Friis	
2,432,134 A	12/1947	Bagnall	
2,540,696 A	2/1951	Smith, Jr. ....	250/33
2,596,966 A	5/1952	Lindsay, Jr. ....	250/33.63
2,648,000 A	8/1953	White .....	250/33.53
2,773,254 A	12/1956	Englemann	
2,836,814 A	5/1958	Nail	
2,968,808 A	1/1961	Russell .....	343/854
3,032,759 A	5/1962	Ashby	
3,032,763 A	6/1962	Sletten	
3,969,729 A	7/1976	Nemit .....	343/756
4,129,872 A	12/1978	Toman .....	343/768

*Primary Examiner*—Richard Elms  
*Assistant Examiner*—Tuan T. Nguyen  
(74) *Attorney, Agent, or Firm*—Welsh & Katz, Ltd.

(57) **ABSTRACT**

An antenna control system enabling the remote variation of antenna beam tilt. A drive means (5, 30) continuously adjusts phase shifters (1, 2, 3; 36, 39, 40) feed distribution network to radiating elements to continuously vary antenna beam tilt. A controller (80) enables the beam tilt of a number of antenna at a site to be remotely varied.

**15 Claims, 8 Drawing Sheets**



U.S. PATENT DOCUMENTS

5,214,364	A	5/1993	Perdue et al. ....	318/600
5,281,974	A	1/1994	Kuramoto et al. ....	343/700
5,440,318	A	8/1995	Butland et al.	
5,488,737	A	1/1996	Harbin et al.	
5,512,914	A	4/1996	Hadzoglou et al. ....	343/816
5,551,060	A	8/1996	Fujii et al.	
5,798,675	A *	8/1998	Drach .....	333/161
5,801,600	A	9/1998	Butland et al. ....	333/127
5,805,996	A	9/1998	Salmela	
5,818,385	A	10/1998	Bartholomew	
5,905,462	A *	5/1999	Hampel et al. ....	342/372
6,188,373	B1 *	2/2001	Martek .....	343/893

FOREIGN PATENT DOCUMENTS

AU	9480057	10/1994
DE	3322-986 A	6/1983
DE	3323-234 A	6/1983
EP	137-562 A	10/1983
EP	241-153 A	4/1986
EP	357-165 A	8/1988
EP	398-637 A	5/1989
EP	423-512 A	10/1989
EP	588179 A1	9/1992
EP	0 618 639	3/1994
EP	0 595 726	5/1994
FR	2 581 255	10/1986
GB	1 314 693	10/1970
GB	1314693	4/1973
GB	2 035 700 A	6/1980
GB	2 158 996 A	11/1985
GB	2 159 333 A	11/1985
GB	2 165 397 A	4/1986
GB	2 196 484 A	4/1988
GB	2 205 946 A	12/1988
GB	2 232 536 A	12/1990
JP	61-172411	8/1986
JP	01-120906	8/1989

JP	02-121504	5/1990
JP	02-174402	7/1990
JP	02-290306	2/1991
JP	04-286407	10/1992
JP	05-121915	5/1993
JP	05-191129	7/1993
JP	06-196927	10/1994
WO	WO 88/08621	10/1988
WO	88/08621	11/1988
WO	WO 95/10862	4/1995

OTHER PUBLICATIONS

Specifications: Mobile Telephone and Panel Array (MTPA) Antenna, VARITILT Continuously Variable Electrical Downtilt Models; Deltec New Zealand Limited.

B. Heath, 1993, "Design Specification for Premium Antenna with EDT and AS".

Friis, 1947, *The Bell System Technical Journal*, XXVI:218-316, "Radar Antennas".

G.E. Bacon, 1946, *Journal I.E.E.*, 93:539-544, "Variable-Elevation Beam-Arial Systems for 1 1/2 Metres".

W.H. Kummer, *Microwave Scanning Antennas*, III:48-130, "Electromechanical Devices".

Mills et al., 1963, *Proceedings of the I.R.E. Australia*, "The Sydney University Cross-type Radio Telescope".

Gary Wilson, 1992, "Electrical Downtilt Through Beam-Steering Versus Mechanical Downtilt".

Yamada et al., NTT Radio Communication Systems Laboratories and Nippon Telegraph and Telephone Corporation, "Low Sidelobe and Tilted Beam Base-Station Antennas for Smaller-Cell Systems".

B. Y. Mills, R. E. Atchison, S.M.I.R.E. (Aust.), A.G. Little and W.B. BcAdam, "The Sydney University Cross-type Radio Telescope", *Proceedings of the I.R.E. Australia*, pp. 156-165.

\* cited by examiner

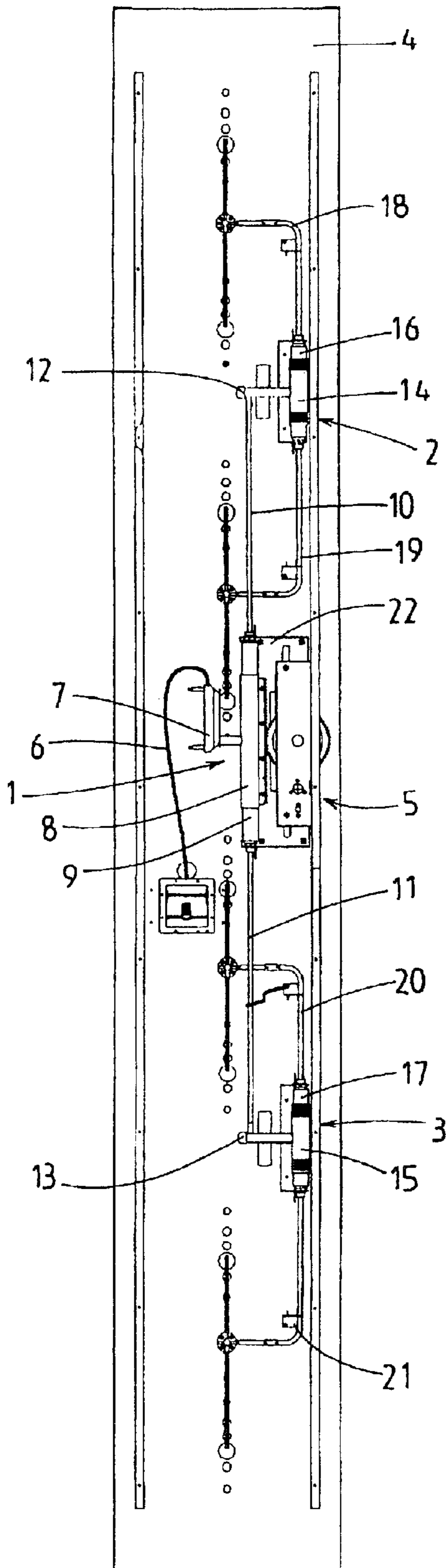


FIG. 1

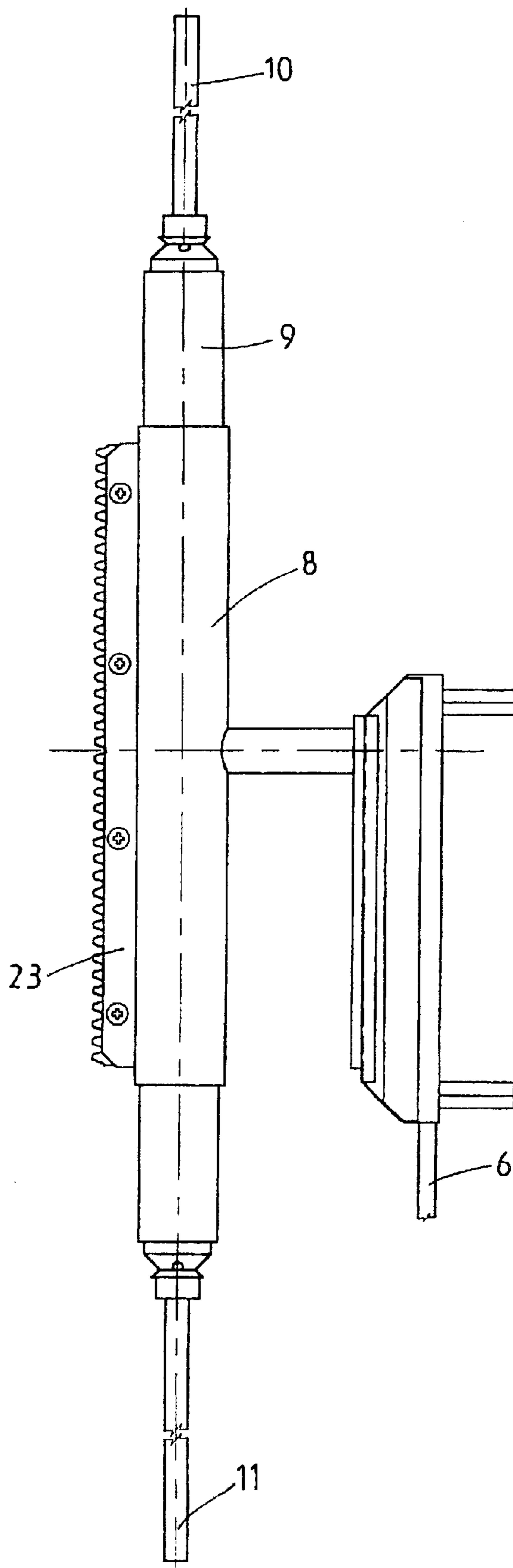


FIG. 2

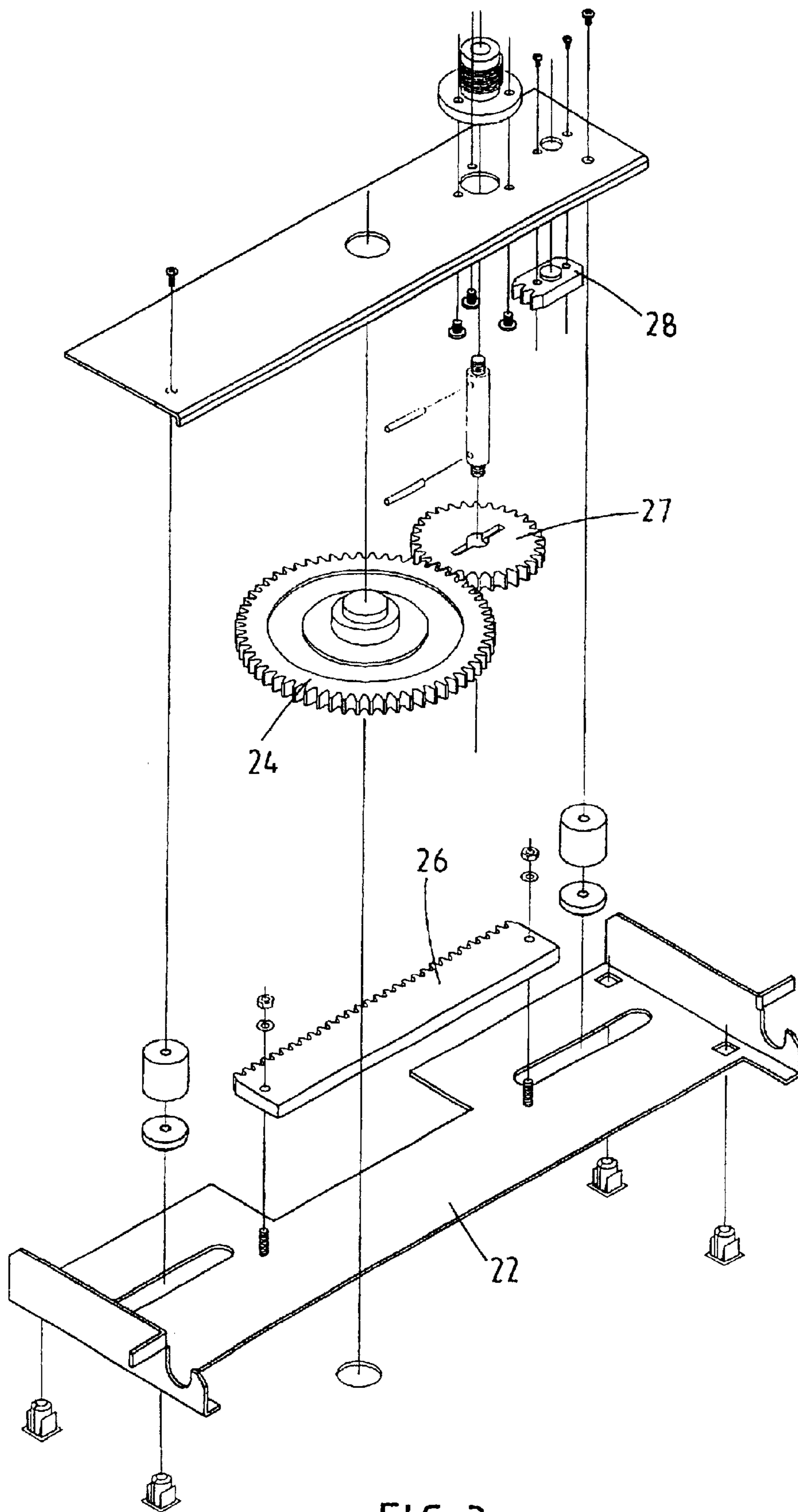


FIG. 3

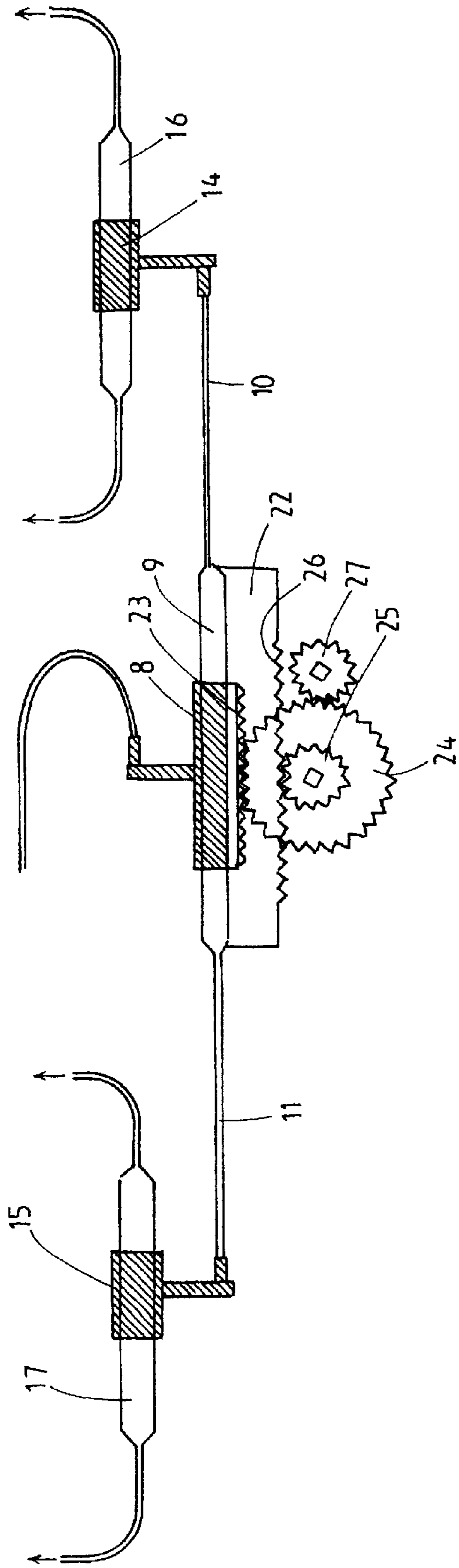


FIG. 4

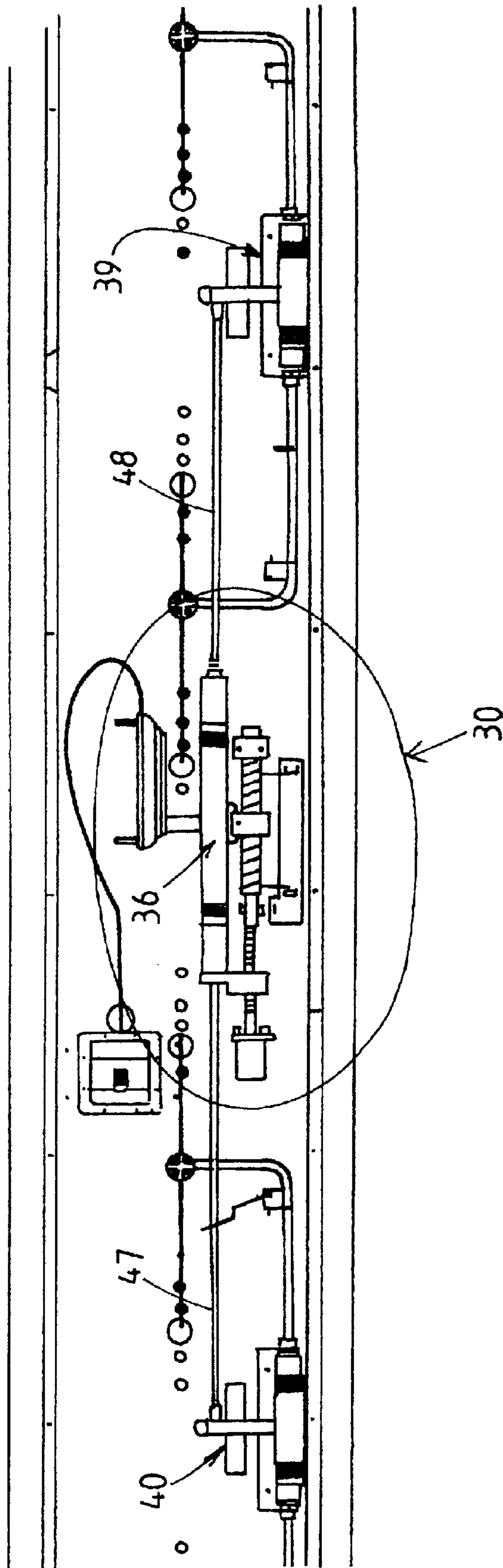


FIG. 5

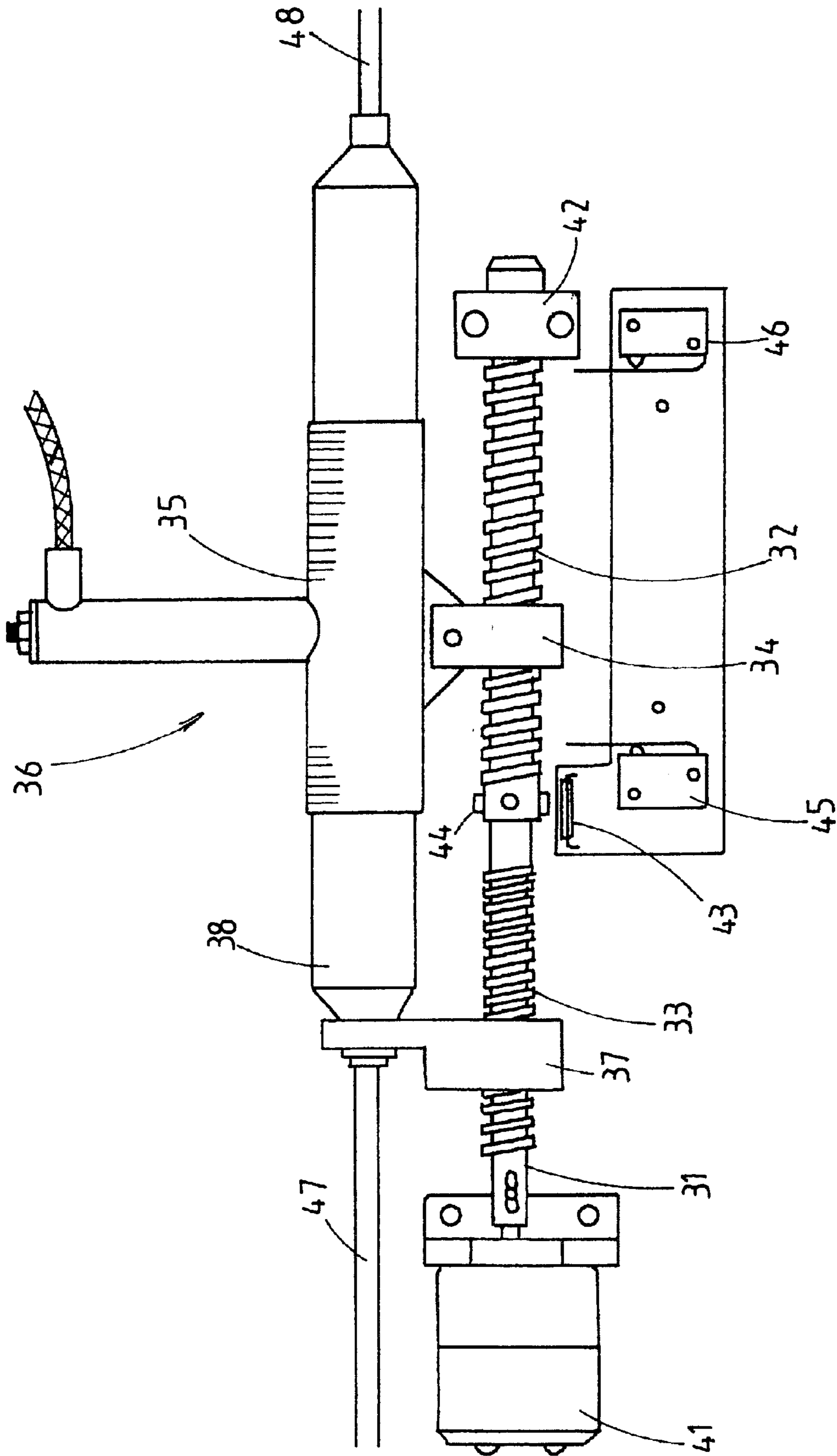


FIG. 6



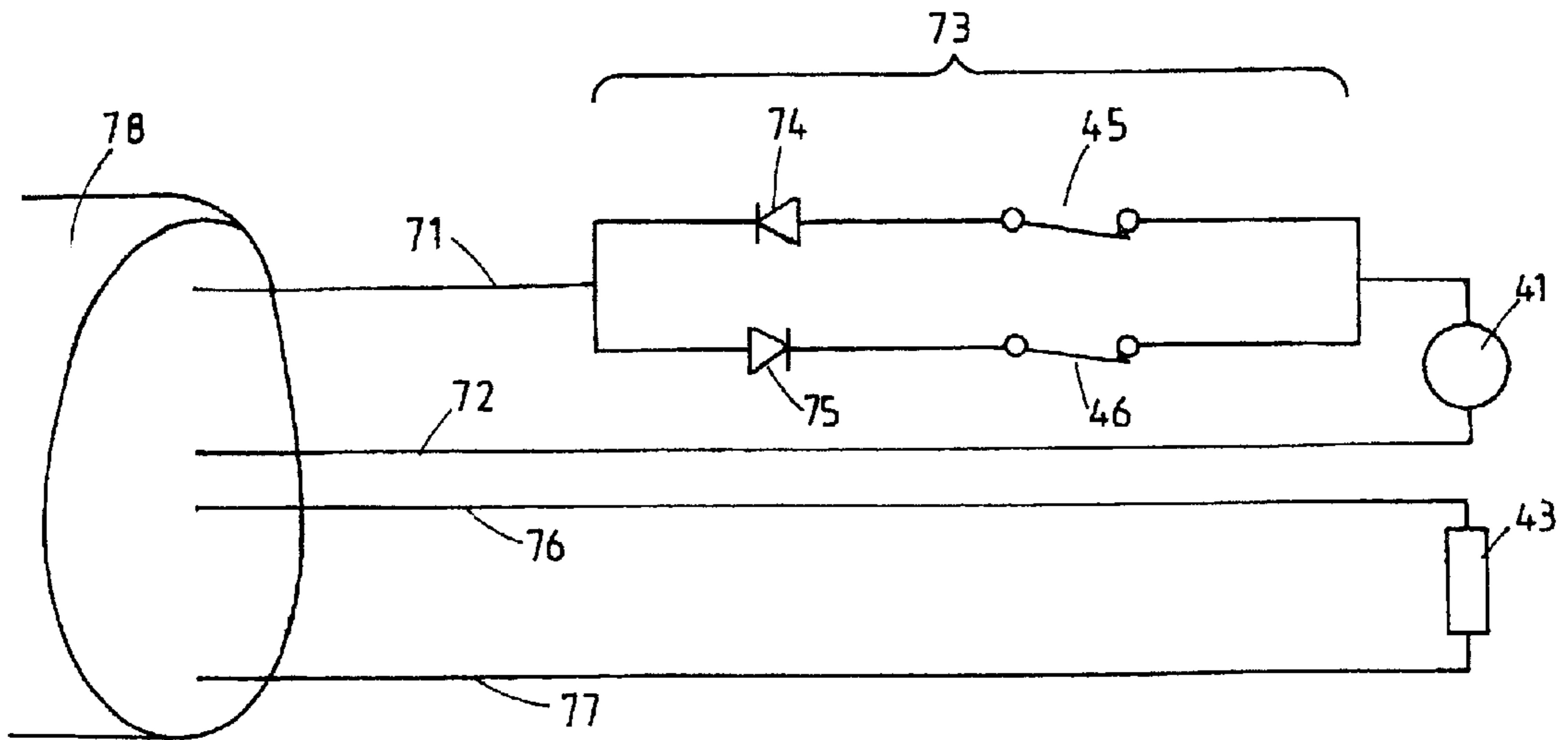


FIG. 7

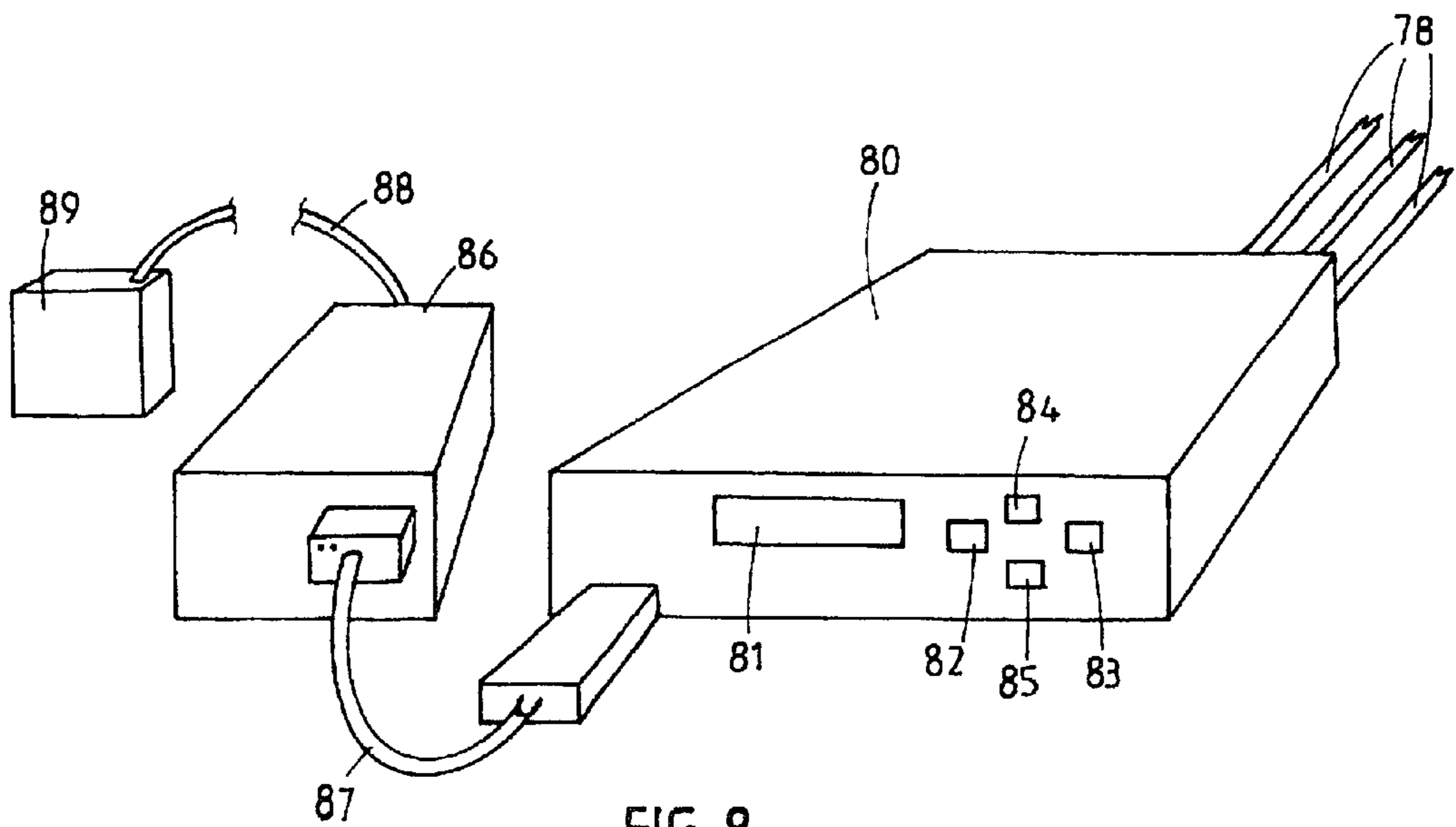


FIG. 8

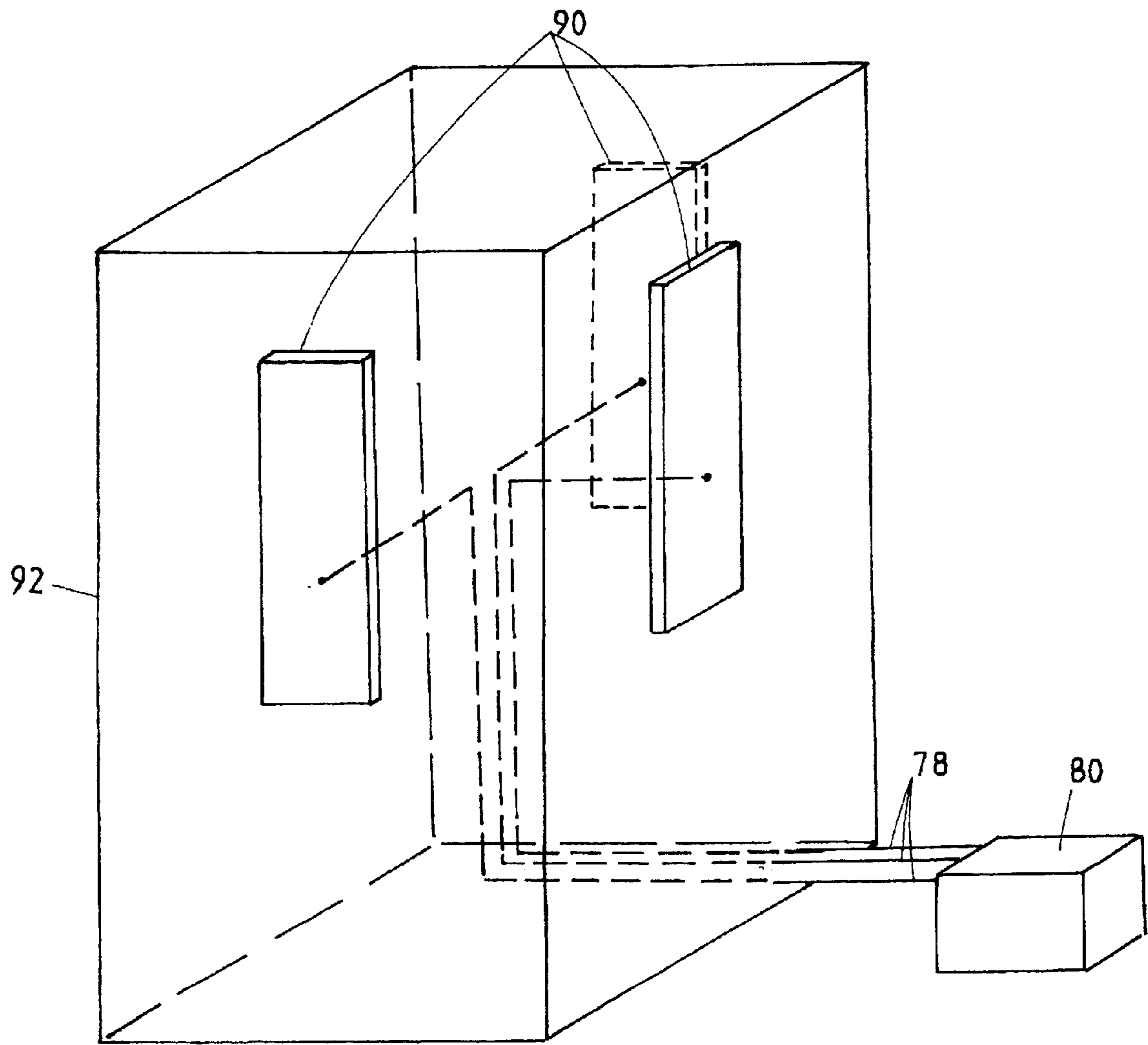


FIG. 9

**ANTENNA CONTROL SYSTEM**

This application is a continuation of PCT National Stage application Ser. No. 08/817,445, filed Apr. 30, 1997 now U.S. Pat. No. 6,198,458, which application(s) are incorporated herein by reference.

**THE TECHNICAL FIELD**

The present invention relates to an antenna control system for varying the beam tilt of one or more antenna. More particularly, although not exclusively, the present invention relates to a drive system for use in an antenna which incorporates one or more phase shifter.

**BACKGROUND OF THE INVENTION**

In order to produce downtilt in the beam produced by an antenna array (for example a panel antenna) it is possible to either mechanically tilt the panel antenna or electrically steer the beam radiated from the panel antenna according to techniques known in the art.

Panel antennas, such as those to which the present application is concerned, are often located on the sides of buildings or similar structures. Mechanical tilting of the antenna away from the side of the building increases the susceptibility of the installation to wind induced vibration and can impact on the visual environment in situations where significant amounts of downtilt are required.

In order to avoid the above difficulties, electrical beam steering can be effected by introducing phase delays into the signal input into radiating elements or groups of radiating elements in an antenna array.

Such techniques are described in New Zealand Patent Specification No. 235010.

Various phase delay techniques are known, including inserting variable length delay lines into the network feeding to the radiating element or elements, or using PIN diodes to vary the phase of a signal transmitted through the feeder network.

A further means for varying the phase of two signals is described in PCT/NZ94/00107 whose disclosure is incorporated herein by reference. This specification describes a mechanically operated variable differential phase shifter incorporating one input and two outputs.

For the present purposes it is sufficient to note that phase shifters such as those described in PCT/NZ94/00107 are adjusted mechanically by sliding an external sleeve along the body of the phase shifter which alters the relative phase of the signals at the phase shifter outputs.

A typical panel antenna will incorporate one or more phase shifters and the present particular embodiment includes three phase shifters. A signal is input to the primary phase shifter which splits the signal into two signals having a desired phase relationship. Each phase shifted signal is then input into a secondary phase shifter whose outputs feeds at least one radiating element. In this manner a progressive phase shift can be achieved across the entire radiating element array, thus providing a means for electrically adjusting the downtilt of the radiated beam. Other phase distributions are possible depending on the application and shape of the radiated beam.

While the steering action is discussed in the context of downtilt of the radiated beam, it is to be understood that the present detailed description is not limited to such a direction. Beam tilt may be produced in any desired direction.

Another particular feature of the variable differential phase shifters is that they provide a continuous phase

adjustment, in contrast with the more conventional stepped phase adjustments normally found in PIN diode or stepped length delay line phase shifters.

In a panel antenna of the type presently under consideration, it is desirable to adjust the entire phase shifter array simultaneously so that a desired degree of beam tilt may be set by the adjustment of a single mechanical setting means. The mechanical drive which performs such an adjustment must result in reproducible downtilt angles and be able to be adapted to provide for a number of different phase shifter array configurations.

It is also desirable that the beam tilt of an antenna may be varied remotely to avoid the need for personnel to climb a structure to adjust antenna beam tilt.

**DISCLOSURE OF THE INVENTION**

It is an object of the present invention to provide a mechanical drive system for use in adjusting mechanical phase shifters which mitigates the abovementioned difficulties, provides a solution to the design requirements of the antennas or antenna arrays described above, or at least provides the public with a useful choice.

Accordingly, there is provided a mechanical adjustment means for adjusting the relative phase shifts produced by a plurality of phase shifters connected to an array of radiating elements, said mechanical adjustment means including:

first means for moving a first portion of a first phase shifter relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and

second means for moving a first portion of a second phase shifter relative to a second portion of said second phase shifter to vary the phase difference between output signals from the second phase shifter, wherein the second phase shifter is fed from an output of the first phase shifter and the degree of movement of the second means is dependent upon the degree of movement of the first means.

Preferably, movement of the second means results in simultaneous movement of a first portion of a third phase shifter with respect to a second portion of the third phase shifter wherein the third phase shifter is fed from an output of the first phase shifter.

Preferably the outputs of the second and third phase shifters are connected to radiating elements so as to produce a beam which tilts as the first and second means adjusts the phase shifters.

Preferably the movement of the first portion of the first phase shifter a first distance relative to the second portion of the first phase shifter results in relative movement between first portions of the second and third phase shifters relative to second portions of the second and third phase shifters of about twice the first distance.

According to a first preferred embodiment the first means includes a gear wheel which drives a rack connected to a first portion of the first phase shifter, arranged so that rotation of the first gear wheel causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter. Preferably, the second portion of the first phase shifter is mounted to a carriage and the outputs of the first phase shifter are connected to inputs of the second and third phase shifters by push rods so that movement of the second portion of the first phase shifter moves the first portions of the second and third phase shifters with respect to the second portions of the second and third phase shifters.

Preferably a second gear is provided co-axial with and connected to a shaft driving the first gear which drives a rack

connected to the second part of the first phase shifter so that rotation of the second gear causes movement of the first portion of the second and third phase shifters relative to the second portions of the second and third phase shifters.

Preferably the ratio between the first and second gear wheels is about 3:1.

According to a second embodiment of the present invention the adjustment means includes a shaft and said first means includes a first threaded portion provided on said shaft and a first cooperating threaded member connected to the first portion of the first phase shifter. The second means includes a second threaded portion provided on said shaft and a second cooperating threaded member connected to the first portion of the second phase shifter. The arrangement is such that rotation of the shaft causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter at a rate of about twice that of the movement of the first portion of the second phase shifter relative to the second portion of the second phase shifter.

Preferably the second threaded member is connected to the second portion of the first phase shifter and moves the first portion of the second phase shifter via a push rod. This push rod is preferably a coaxial line connecting an output from the first phase shifter to the input to the second phase shifters

Preferably there is further provided a third phase shifter fed from a second output of the first phase shifter via a push rod which moves a first portion of the third phase shifter in unison with the first portion of the second phase shifter.

According to a further aspect of the invention there is provided an antenna system comprising one or more antenna including electromechanical means for varying the downtilt of the antenna and a controller, external to the antenna, for supplying drive signals to the electromechanical means for adjusting downtilt.

Preferably the system includes a plurality of antenna and the controller may adjust the downtilt for the plurality of antenna and store the degree of downtilt of each antenna in memory.

Preferably the controller may be controlled remotely from a control centre so that a plurality of such systems may be remotely controlled as part of a control strategy for a number of cellular base stations.

Preferably the electromechanical means varies the electrical downtilt of each antenna and means are included for monitoring the electromechanical means and providing signals representative of the position of the electromechanical means to the controller.

#### BRIEF DESCRIPTIONS OF THE DRAWINGS

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 shows a panel antenna incorporating a phase shifter drive mechanism according to a first embodiment of the invention.

FIG. 2 illustrates a primary phase shifter incorporating a gear rack.

FIG. 3 illustrates an exploded view of the adjustment assembly incorporated into the carriage.

FIG. 4 shows diagrammatically the operation of the drive mechanism according to the first embodiment.

FIG. 5 shows a panel antenna incorporating a phase shifter drive mechanism according to a second embodiment of the invention.

FIG. 6 shows the phase shifter drive mechanism of FIG. 5 in detail.

FIG. 7 shows the electrical connection of the motor, switches and reed switch of the drive mechanism shown in FIG. 6.

FIG. 8 shows a controller for controlling the drive mechanism shown in FIGS. 6 and 7.

FIG. 9 shows an antenna system according to one aspect of the present invention having a plurality of antennas controlled by a controller.

#### BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1 there is shown the back side of a panel antenna 4 having a first phase shifter 1, a second phase shifter 2, a third phase shifter 3 and a phase shifter drive mechanism 5. Feed line 6 is connected to input 7 of phase shifter 1. A first portion 8 of phase shifter 1 is moveable relative to a second portion 9 of phase shifter 1.

Output signals from phase shifter 1 are supplied via lines 10 and 11 to inputs 12 and 13 of phase shifters 2 and 3 respectively. Feed lines 10 and 11 comprise coaxial push rods which serve the functions both of feeding signals from the outputs of phase shifter 1 to phase shifters 2 and 3 and moving first portions 14 and 15 of phase shifters 2 and 3 relative to second portion 16 and 17 of phase shifters 2 and 3 respectively.

Signals output from phase shifters 2 and 3 are supplied via coaxial lines 18, 19, 20 and 21 to be fed to respective radiating elements (not shown).

In use first portion 8 of phase shifter 1 may be moved relative to second portion 9 of phase shifter 1 to change the relative phase of signals supplied via lines 10 and 11 to phase shifters 2 and 3 respectively. First portions 14 and 15 of phase shifters 2 and 3 may be moved relative to second portions 16 and 17 of phase shifters 2 and 3 to vary the phase of signals supplied by lines 18, 19, 20 and 21 to respective radiating elements.

When phase shifters 1, 2 and 3 are adjusted in the correct respective portions the beam emitted by the antenna can be tilted as required. It will be appreciated that where a less defined beam is required fewer phase shifters may be employed.

To achieve even continuous beam tilting for the embodiment shown in FIG. 1 the first portions 14 and 15 of phase shifters 2 and 3 should move relative to the second portion 16 and 17 of phase shifters 2 and 3 at the same rate. The first portion 8 of phase shifter 1 must however move relative to the second portion 9 of phase shifter 1 at twice this rate. In the arrangement shown second portion 9 of phase shifter 1 is connected to carriage 22. Movement of carriage 22 results in movement of first portions 14 and 15 of phase shifters 2 and 3 via push rods 10 and 11.

Referring now to FIG. 4, operation of the phase shifter drive mechanism will be explained. Second portion 9 of phase shifter 1 is mounted to a carriage 22 which can move left and right. If carriage 22 is moved to the left first portions 14 and 15 of phase shifters 2 and 3 will be moved to the left via push rods 10 and 11. First portion 8 of phase shifter 1 may be moved relative to phase shifter 9 to vary the phase of signal supplied to phase shifters 2 and 3.

According to this first embodiment a rack 23 is secured to first portion 8 of phase shifter 1. Upon rotation of gear wheel 24 first portion 8 of phase shifter 1 may be moved to the left or the right. A smaller gear wheel 25 is secured to and rotates with gear wheel 24. This gear wheel engages with a rack 26 provided on carriage 22. A further gear wheel 27 is provided

which may be driven to rotate gear wheels **24** and **25** simultaneously.

Gear wheel **24** has **90** teeth whereas gear wheel **25** has **30** teeth. It will therefore be appreciated that rotation of gear wheel **24** results in first portion **8** of phase shifter **1** being moved three times as far as carriage **22** (and hence first portions **14** and **15** of phase shifters **2** and **3**). However, as carriage **22** is moving in the same direction as the first portion **8** of phase shifter **1** it will be appreciated that the relative movement between first portion **8** and second portion **9** of phase shifter **1** is twice that of the relative movement between the first and second portions of phase shifters **2** and **3**. Accordingly, this arrangement results in the relative phase shift produced by phase shifter **1** being twice that produced by phase shifters **2** and **3** (as required to produce even beam tilting in a branched feed arrangement).

The particular arrangement is shown in more detail in FIGS. **2** to **4**. It will be appreciated that gear wheel **27** may be driven by any appropriate manual or driven means. Gear wheel **27** may be adjusted by a knob, lever, stepper motor or other driven actuator. A keeper **28** may be secured in place to prevent movement once the desired settings of the phase shifters have been achieved.

Referring now to FIGS. **5** and **6**, a second embodiment will be described. As seen in FIG. **5**, the arrangement is substantially the same as that shown in the first embodiment except for the drive mechanism employed, which is shown in FIG. **6**.

In this embodiment the drive mechanism includes a shaft **31** having a first threaded portion **32** and a second threaded portion **33** provided thereon. A first threaded member **34** is connected to a first portion **35** of primary phase shifter **36**. A second threaded member **37** is connected to the second portion **38** of primary phase shifter **36**.

First threaded portion **32** is of three times the pitch of second threaded portion **33** (e.g. the pitch of the first threaded portion **32** is 6 mm whereas the pitch of the second threaded portion is 2 mm). In this way, first portion **35** is driven in the direction of movement at three times that of second portion **38**. In this way the phase shift produced by primary phase shifter **36** is twice that of second and third phase shifters **39** and **40**.

Shaft **31** is rotated by motor **41**. This may suitably be a geared down 12 volt DC motor. The other end of shaft **31** is supported by end bearing **42**. A reed switch **43** is provided to detect when magnets **44** pass thereby. In this way the number of rotations of shaft **31** may be monitored. Limit switches **45** and **46** may be provided so that the motor is prevented from further driving shaft **31** in a given direction if threaded member **34** abuts a lever of limit switch **45** or **46** respectively.

Operation of the drive means according to the second embodiment will now be described by way of example. Motor **41** may rotate shaft **31** in an anticlockwise direction, viewed from right to left along shaft **3**. Threaded member **37** is driven by second threaded portion **33** to move push rods **47** and **48** to the left, and thus to adjust phase shifters **39** and **40**.

Threaded member **34** is driven to the left at three times the rate of threaded member **37**. First portion **35** thus moves to the left at three times the rate of second portion **38**. First portion **35** therefore moves relative to second portion **38** at twice the speed the first portions of phase shifters **39** and **40** move relative to their respective second portions. In this way, delays are introduced in the paths to respective radiating elements so as to produce an evenly tilting beam.

The conductivity of reed switch **43** is monitored so that the number of rotations, or part rotations, of shaft **31** may be monitored. If the motor continues driving shaft **31** until threaded member abuts the lever of limit switch **45** then logic circuitry will only permit motor **41** to drive in the opposite direction. Likewise if threaded member **34** abuts the lever of limit switch **46** the motor **41** will only be permitted to drive in the opposite direction.

It will be appreciated that the techniques of both embodiments could be employed in antenna arrays using a larger number of phase shifters. In such applications the relative movement of the first portion of each phase shifter relative to the second portion of each phase shifter would be decreased by a factor of 2 for each successive phase shifter along each branch. The ratios used may be varied if the radiation pattern of the antenna needs to be altered to account for the directivity of the individual radiating elements and the effect of the back panel as the amount of downtilt is varied.

Components of the drive mechanism are preferably formed of plastics, where possible, to reduce intermodulation. Threaded members **34** and **37** preferably include plastic links to phase shifter **36** to reduce intermodulation.

It will be appreciated that a number of mechanical drive arrangements may be used to achieve adjustment of the phase shifters in the desired ratio. It is also to be appreciated that sophisticated control electronics may be employed, although the simplicity of construction of the present invention is seen as an advantage.

FIG. **7** shows how motor **41**, reed switch **43** and switches **45** and **46** are connected to lines **71**, **72**, **76** and **77** from an external controller. Lines **71** and **72** supply current to drive motor **41**. Section **73** ensures that if threaded member **34** is driven to either the left-hand side limit or the right-hand side limit it can only be driven in the opposite direction. In the position shown in FIG. **7**, switch **45** directly connects line **71** to switch **46** via diode **74**. In the position shown switch **46** connects line **71** to motor **41** via diode **75**. This is the normal position of the switches when threaded member **34** is not at either extreme limit. When threaded member **34** is driven to the extreme left, for example, and actuates switch **45**, then switch **45** open circuits the path via diode **74**. Diode **74** allows current flow in the direction allowing motor **41** to drive to the left. Accordingly, when switch **45** is open, motor **41** can only drive in such a direction as to drive threaded member **34** to the right (i.e.: current in the direction allowed by diode **75**).

Likewise, if threaded member **34** is driven to the extreme right, switch **46** is opened to break the path via diode **75**. This prevents motor **41** driving in such a direction as to drive threaded member **34** further to the right.

Lines **76** and **77** are connected to reed switch **43** so that the opening and closing of reed switch **43** may be monitored by an external control unit. In use, the opening and closing of reed switch **43** may be monitored to determine the position of threaded member **34**, and hence the corresponding degree of tilt of the antenna.

To select an initial angle of downtilt threaded member **34** may be driven to the extreme right. An external controller may provide a current in one direction to motor **41** to drive member **34** to the right. The motor will continue to be driven to the right until threaded portion **34** abuts switch **46**. When switch **46** is opened diode **75** will be open circuited, which will prevent the motor being driven further to the right.

The controller will sense that threaded member **34** is at its extreme right position as it will detect that reed switch **43** is not opening and closing. After a predetermined delay the controller may then provide a current in the opposite direction via lines **71** and **72** to motor **41** to drive it to the left. As the motor is driven to the left the controller will monitor the opening and closing of reed switch **43** to determine how far threaded member **34** has moved to the left. The controller will continue to move threaded member **34** to the left until reed switch **43** has opened and closed a predetermined number of times, corresponding to a desired angle of downtilt. Alternatively, member **34** may be driven to the extreme left and then back to the right.

At an antenna site a number of such panels may be installed and controlled by a single controller **80** as shown in FIG. **8**. The four wires **71**, **72**, **76** and **77** correspond to respective cable groups **78** to three such antenna panels. Controller **80** may be provided at the base of an antenna site to allow an operator to adjust the tilt of a plurality of antennas at ground level, rather than requiring a serviceman to climb up the antenna structure and adjust each antenna manually. Alternatively, controller **80** may be a hand-held unit which can be plugged into a connector at the base of an antenna to adjust antenna at a site.

Controller **80** may include a display **81**, an "escape" button **82**, an "enter" button **83**, an "up" button **84** and "down" button **85**. At power up display **81** may simply display a home menu such as "Deltec NZ Ltd© 1995". Upon pressing any key, a base menu may be displayed including options such as:

```
unlock controls
set array tilt
measure tilt
enable array
disable array
lock controls
```

The up/down keys may be used to move through the menu and the enter key **83** used to select an option. If "unlock controls" is selected a user will then be required to enter a three digit code. The up/down keys may be used to move through the numbers 0 to 9 and enter used to select each number. If the correct code is entered "locked released" appears. If the incorrect code is entered "controls locked" appears and a user is returned to the home menu. If "set array tilt" is selected from the base menu the following may appear:

```
set array tilt
array:01 X.X°
```

The up-down keys **84**, **85** may be used to select the desired array number. The enter key accepts the selected array and the previously recorded angle of downtilt may be displayed as follows:

```
set array tilt
array: 01 4.6°
```

In this example the previously set angle of downtilt with 4.60°. Using the up/down keys **84**, **85** a new angle may be entered. Controller **80** may then provide a current to motor **41** via lines **71** and **72** to drive threaded portion **34** in the desired direction to alter the downtilt. The opening and closing of reed switch **43** is monitored so that threaded member **34** is moved in the desired direction for a predetermined number of pulses from reed switch **43**. The downtilt for any other array may be changed in the same manner. If the controller is locked a user may view an angle of downtilt but will not be able to alter the angle.

If the "measure array" option is selected the present angle of downtilt of the antenna may be determined. Upon selecting the "measure tilt" function from the base menu, the following display appears:

```
measure tilt
array: 01 X.X°
```

The up/down buttons may be used to select the desired array. The enter key will accept the selected array. To measure the actual angle of downtilt controller **80** drives a motor **41** of an array to drive member **34** to the right. Motor **41** is driven until threaded member **34** abuts switch **46**. The controller counts the number of pulses from reed switch **43** to determine how far threaded portion **34** has travelled. At the extreme right position the controller determines and displays the angle of downtilt, calculated in accordance with the number of pulses connected from reed switch **43**. The controller then drives threaded member **34** back in the opposite direction for the same number of pulses from reed switch **43** so that it returns to the same position. The angle of downtilt for each antenna may be stored in memory of controller **80**. This value will be updated whenever the actual angle of downtilt is measured in this way. The "measure tilt" function may not be used if the controller is locked.

Controller **80** may include tables in memory containing the number of pulses from reed switch **43** that must be counted for threaded member **34** to achieve each desired degree of downtilt. This may be stored as a table containing the number of pulses for each required degree of downtilt, which may be in 0.1° steps. This approach ensures that any non-linearities of the antenna may be compensated for as the tables will give the actual amount of movement required to achieve a desired downtilt for a given antenna.

The "enable array" function may be used to enable each array when installed. The controller will be prevented from moving any array that has not been enabled. Controller **80** will record in memory which arrays have been enabled. The "disable array" function may be used to disable arrays in a similar manner.

The "lock controls" function may be used to lock the controller once adjustment has been made. A "rack error" signal may be displayed if the array has not operated correctly. This will indicate that an operator should inspect the array.

Adjustment of the array may also be performed remotely. Controller **80** may be connected to modem **86** via serial line **87** which may connect via telephone line **88** to a central controller **89**. Alternatively, the controller **80** may be connected to a central controller **89** via a radio link etc. The functions previously discussed may be effected remotely at central controller **89**. In a computer controlled system adjustments may be made by a computer without operator intervention. In this way, the system can be integrated as part of a control strategy for a cellular base station. For example, a remote control centre **89** may adjust the downtilt of antennas at a cellular base station remotely to adjust the size of the cell in response to traffic demand. It will be appreciated that the capability to continuously and remotely control the electrical downtilt of a number of antenna of a cellular base station may be utilised in a number of control strategies.

Central controller **89** may be a computer, such as an IBM compatible PC running a windows based software program. A main screen of the program may show information regarding the antenna under control as follows:

GROUP 1	NAME	TYPE ANGLE	CURRENT VALUE	NEW	STATUS
antenna 1	1 south	VT01	12°	12.5°	setting
antenna 2	1 north	VT01	12°	12.5°	queued
antenna 3	1 west	VT01	12°	12.5°	queued

GROUP 2	NAME	TYPE	CURRENT ANGLE	NEW VALUE	STATUS
antenna 4	2 south	VT01	6°		pending
antenna 5	2 north	VT01	6°	.5°	nudging
antenna 6	2 west	VT01	6°		faulty

The antennas may be arranged in groups at each site. Group 1 for example contains antennas 1, 2 and 3. The following information about each antenna is given:

Name: this is the user assigned name such as 1 south, 1 north, 1 west etc.

Type: this is the antenna type which the controller communicates to the PC at start-up.

Current Angle: this is the actual degree of beam tilt of an antenna which is communicated from the controller to the PC at start-up. The controller also supplies to the PC each antenna's minimum and maximum angles of tilt.

New Value: by moving a pointer to the row of an antenna and clicking a button of a mouse the settings of an antenna may be varied. When a user clicks on the mouse the following options may be selected:

Name—the user may change the group or antenna name.

Adjust—a user may enter a new angle in the “new value” column to set the antenna to a new value.

Nudge—the user may enter a relative value (i.e.: increase or decrease the tilt of an antenna by a predetermined amount).

Measure—the controller may be instructed to measure the actual angle of tilt of an antenna or group of antennas.

If an antenna is in a “fault” condition then it may not be adjusted and if a user clicks on a mouse when that antenna is highlighted a dialogue box will appear instructing the user to clear the fault before adjusting the antenna.

Each antenna also includes a field indicating the status of the antenna as follows:

O.K.—the antenna is functioning normally.

Queued—an instruction to read, measure, set or nudge the antenna has been queued until the controller is ready.

Reading—when information about an antenna is being read from the controller.

Measuring—when the actual degree of tilt of the antenna is being measured.

Setting—when a new tilt angle is being set.

Nudging—when the tilt angle of the antenna is being nudged.

Faulty—where an antenna is faulty.

When adjusting, measuring or nudging an antenna a further dialogue box may appear describing the action that has been instructed and asking a user to confirm that the action should be taken. This safeguards against undesired commands being carried out.

Information for a site may be stored in a file which can be recalled when the antenna is to be monitored or adjusted again. It will be appreciated that the software may be modified for any required control application.

Controller **80** may be a fixed controller installed in the base of an antenna site or could be a portable control unit which is plugged into connectors from control lines **78**.

Where in the foregoing description reference has been made to integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention.

#### INDUSTRIAL APPLICABILITY

The present invention may find particular application in antenna systems, such as those used in cellular communication systems.

What is claimed is:

1. A panel antenna, comprising:

a back panel having a back side and a front side;

a plurality of radiating elements mounted on the back panel;

a plurality of phase shifters mounted on the backside of the back panel and connected to the plurality of radiating elements; and

a drive mechanism configured to adjust the relative phase shifts produced by the plurality of phase shifters said drive mechanism including:

a first translator configured to move a first portion of a first phase shifter of the plurality of phase shifters relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and

a second translator configured to move a first portion of a second phase shifter of the plurality of phase shifters relative to a second portion of said second phase shifter to vary the phase difference between output signals from the second phase shifter, wherein the second phase shifter is fed from an output of the first phase shifter and the degree of movement of the second translator is dependent upon the degree of movement of the first translator.

2. The panel antenna as claimed in claim 1 wherein movement of the second translator causes simultaneous movement of a first portion of a third phase shifter of the plurality of phase shifters with respect to a second portion of the third phase shifter, wherein the third phase shifter is fed from an output of the first phase shifter.

3. The panel antenna as claimed in claim 2 wherein the outputs of the second and third phase shifters are connected to the plurality of radiating elements so as to produce a beam which tilts as the first and second translators adjust the phase shifters.

4. The panel antenna as claimed in claim 2 wherein movement of the first portion of the first phase shifter a first distance relative to the second portion of the first phase shifter results in relative movement between first portions of the second and third phase shifters relative to second portions of the second and third phase shifters of about twice the first distance.

5. The panel antenna as claimed in claim 2 wherein the first translator includes a first gear wheel which drives a rack connected to the first portion of the first phase shifter,

## 11

arranged so that rotation of the first gear wheel causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter.

6. The panel antenna as claimed in claim 5, wherein the second portion of the first phase shifter is mounted to a carriage and the outputs of the first phase shifter are connected to inputs of the second and third phase shifters by push rods so that movement of the second portion of the first phase shifter moves the first portions of the second and third phase shifters with respect to the second portions of the second and third phase shifters.

7. The panel antenna as claimed in claim 5, wherein a second gear wheel is provided, driven with the first gear wheel, which drives a rack connected to the second portion of the first phase shifter so that rotation of the second gear wheel causes movement of the first portions of the second and third phase shifters relative to the second portions of the second and third phase shifters.

8. The panel antenna as claimed in claim 7 wherein the ratio between the first and second gear wheels is about 3:1.

9. The panel antenna as claimed in claim 1, wherein the drive mechanism includes a shaft and said first translator includes a first threaded portion provided on said shaft and a first cooperating threaded member connected to the first portion of the first phase shifter, the second translator includes a second threaded portion provided on said shaft and a second cooperating threaded member connected to the first portion of the second phase shifter, the arrangement being such that rotation of the shaft causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter at a rate that is a multiple of the movement of the first portion of the second phase shifter relative to the second phase shifter.

## 12

10. The panel antenna as claimed in claim 9 wherein the multiple is about 2.

11. The panel antenna as claimed in claim 9 wherein the second threaded member is connected to the second portion of the first phase shifter and moves the first portion of the second phase shifter via a push rod.

12. The panel antenna as claimed in claim 11 wherein the push rod is a coaxial line connecting an output from the first phase shifter to the input of the second phase shifter.

13. The panel antenna as claimed in claim 9 including a third phase shifter of the plurality of phase shifters fed from a second output of the first phase shifter via a push rod which moves a first portion of the third phase shifter in unison with the first portion of the second phase shifter.

14. A panel antenna comprising:

a back panel having a front side and a back side;

two or more radiating elements mounted on the front side of the back panel;

one or more phase shifters connected to the two or more radiating elements and mounted on the back side of the back panel; and

electromechanical means mounted on the back side of the back panel and responsive to externally supplied drive signals for relatively moving components of the one or more phase shifters to vary the phase of signals supplied to the respective radiating elements to vary beam tilt of the beam of the panel antenna.

15. An antenna system comprising a panel antenna according to claim 14, and a controller, external to the panel antenna, for supplying drive signals to the electromechanical means.

\* \* \* \* \*